J. Pure Appl. & Ind. Phys. Vol.3 (4), 243-246 (2013)

Long-term Relationship Between Cosmic Ray Intensity and Solar Activity

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(Received on: July 11, 2013)

ABSTRACT

The relationship between long-term cosmic ray intensity and sunspot numbers have been investigated for the period of 1976 to 2008 covering the solar cycle 21 to 23.The correlation coefficients between cosmic rays and sunspot number are found high and negative, which varies randomly from one year to another. Correlations between these two solar and cosmic ray indices for solar cycle 22 are differ from solar cycle 23.Almost same correlation coefficients are observed in ascending and descending phases of solar cycle 22, whereas significant difference is observed for solar cycle 23.

Keywords: Cosmic rays, sunspot number, solar cycle.

INTRODUCTION

The cosmic ray intensity, as it is observed on earth surface exhibits 11 year variation firstly studied by Forbush[1]. Many research groups have tried to express this long-term cosmic ray intensity variation in relation with solar activity and geomagnetic parameters. The solar modulation of cosmic ray intensity has been investigated continuously since last five decades using the ground based neutron and meson monitors[2-3]. In earlier research Nagashima *et al.*[4] have obtained a better correlation between cosmic ray intensity and solar activity using spherical harmonics of solar magnetic field. From the beginning of solar modulation of cosmic ray studies, sunspot numbers have been used as the most reliable parameter representing the variations of solar activity. Sunspots are known to produce solar flares, solar wind and other short/long period phenomena on the surface of sun, which in turn propagate their energy through solar wind and interplanetary magnetic field to long distances in the

interplanetary medium in turn, affect the energetic cosmic ray particles. The cosmic ray modulation is a complex phenomenon which occurs all over the heliosphere and depends upon many factors. No single solar or interplanetary index can account for cosmic ray variations. Emission of matter and electromagnetic fields from the sun increases during high solar activity period, making it harder for galactic cosmic ray to reach on earth surface. Cosmic ray intensity is lower when solar activity is high. We can say that the empirical model proposed in the previous works with significant improvements has been studied finally for a lot of solar cycles 21, 22, and 23, and the obtained results are a confirmation of the reliability of this. In a future work, we hope that the consideration of another solar parameter such as the polar magnetic field of the Sun will be able to throw more light to the investigation of the long-term cosmic ray modulation. In the present work, we have done a detail correlative study to derive the relationship of cosmic rays with sunspot numbers for the solar cycle 21 to 23.

DATA AND METHOD OF ANALYSIS

In order to study the long-term cosmic ray modulation through the years 1976 to 2008, monthly mean values of cosmic rays from Kiel and Moscow neutron monitors were used. For the purpose of this study, the time series of cosmic rays was normalizes taking the cosmic ray intensity maximum (Feb-March, 1987) equal to 100. In this study we have also used data of the mean monthly sunspot.

RESULTS AND DISCUSSION

Using the monthly mean values of cosmic rays and sunspot numbers Rz, the correlation coefficients are derived for each year starting from 1976 to 2008.To show the variation profiles of cosmic ray data for the three successive solar cycles 21 to 23, we plotted the yearly mean values of cosmic ray Kiel and Moscow along with sunspot numbers as shown in figure 1. The figure quite clearly reveals the anti8 phase of cosmic rays with solar sunspot numbers. Long-term variation profiles of solar cycle 21 and 23 are found to be almost similar and differ from the solar cycle 22, which also support the odd-even hypothesis in long-term cosmic ray modulation. On the other hand in case of solar activity, variation in sunspot number for solar cycle 23 shows unusual behavior. One can observe long minima during the end of solar cycle 23.In figure 2, we have plotted the yearly values of correlation coefficients between cosmic rays (Kiel) and sunspot number Rz for the period of 1976 to 2008.It is concluded from the figure that most of years show high and negative correlation. However some years particularly high and minimum solar activity years show poor correlations.

It is also noted from the analysis that solar cycle 23 is peculiar and differs from another solar cycle. The response of cosmic ray particles to solar activity during different solar activity cycle is different. As we know that the heliomagnetic cycle lasts about 212 years due to the reversing action of the sun's

magnetic field around sunspot maxima, there is an opposite sign of magnetic dipole moment during consecutive heliomagnetic cycles[5]. Hence charged particles in interplanetary medium may suffer the effects from gradient and curvature of interplanetary magnetic field.

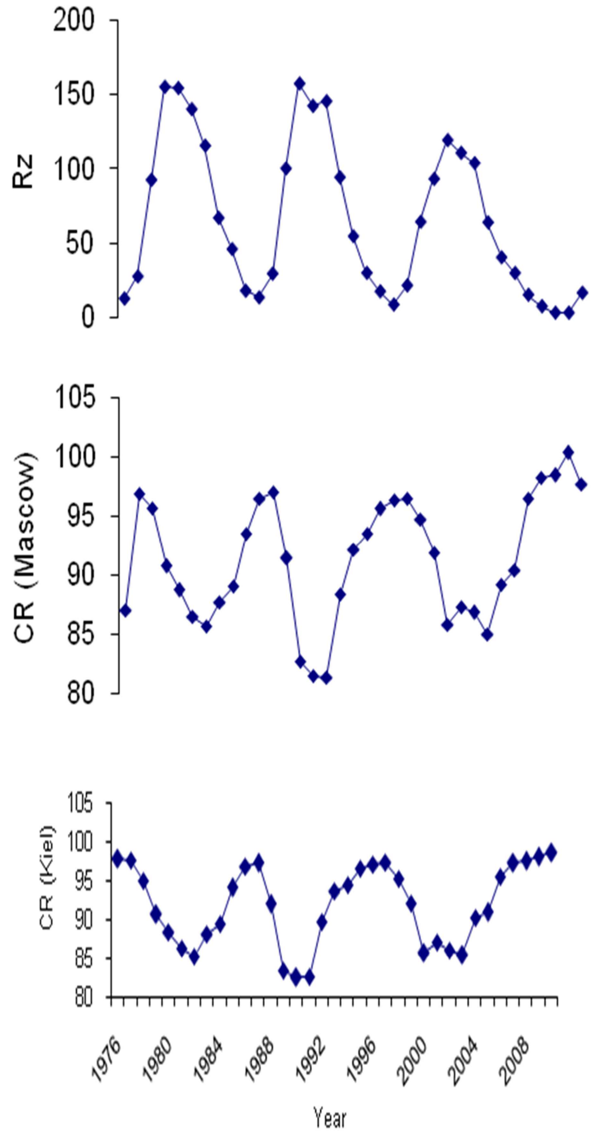

Figure 1. Shows the yearly mean values of Kiel and Moscow neutron monitor cosmic ray along with sunspot numbers for the period of 1976 to2010.

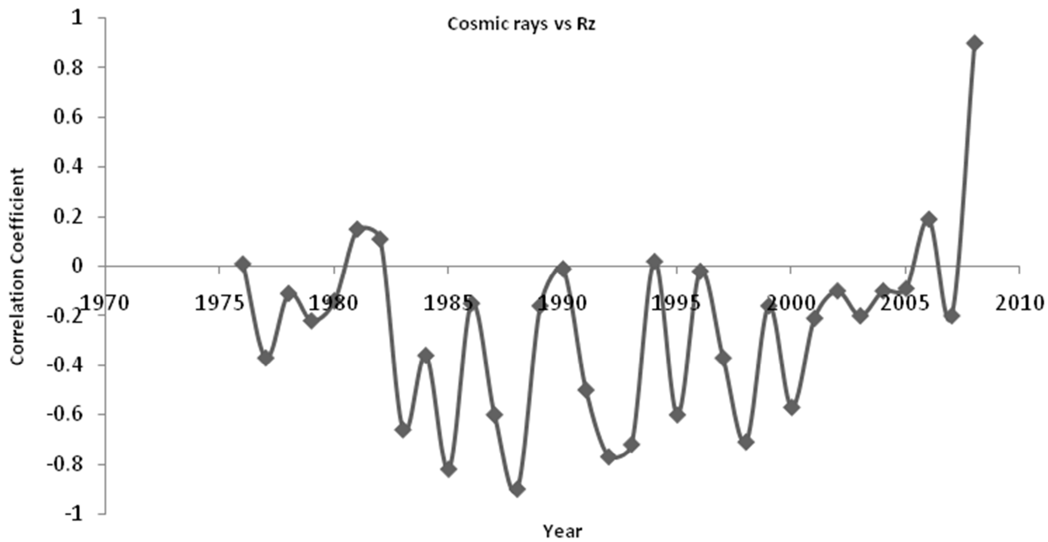

Figure 2. The correlation coefficients for each year for one pairs of values derived from the corresponding twelve monthly values between cosmic rays and Rz.

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